



Improved modelling of bud-burst date of herbaceous plants coupling the effect of heat and water

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Modelling phenology of herbaceous plants is difficult since it is correlated with multiple environmental factors, e.g. temperature, precipitation and soil moisture, and the correlation often varied among species. The integrated effect of heat and water on phenology of herbaceous plants is seldomly considered in existing models. Here, we systematically studied how bud-burst date (BBD) of four common herbaceous species (*Xanthium sibiricum*, *Plantago asiatica*, *Iris lacteal* and *Taraxacum mongolicum*) in Inner Mongolia responded to climatic factors through partial correlation analysis. Subsequently, we used two existing temperature-based models and ten modified models with relevant climatic factors to simulate the BBD of these four species. For each species, the temporal-spatial pattern of BBD simulated by optimal model in Inner Mongolia over the past 30 years was further studied. The results showed that: (1) The increase in temperature would lead to an advance in BBD of all the herbaceous plants, but the influence of precipitation and soil moisture was species-specific. (2) The modified models simulated BBD with lower root mean square errors (RMSE), smaller Akaike information criterion (AIC) and larger coefficient of determination (R^2) than the classical temperature-based models. The RMSE of simulated BBD from the optimal model ranged from 9.03 to 11.97 days. (3) A significant advancing trend was found in BBD of the four species in majority areas in Inner Mongolia over the past 30 years. Our findings suggested that the influence of water and heat needed to be considered in predicting the phenological response of individual herbaceous species to climate change.